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Petrographic Study of Chhotanagpur Granite Rocks with Special Reference to REE Estimation from Tupudana & Khunti area, Ranchi, Jharkhand, India

SYNOPSIS
Submitted

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1. INTRODUCTION:

In modern world, rare earth elements (REE) govern the industrial advancement and the economy of country. Rare earth elements are distributed widely in the earth's crust. The estimated average concentration of REE in the Earth's crust which ranges from around 130µg/g to 240µg/g which is significantly higher than other commonly exploited elements. China is home to most of these reserves, which total 44 million MT and production rate of 240,000 MT in 2023. Based on reserve volume, China is the leading country for rare earth elements, followed by Vietnam, Russia, Brazil, India, and Australia. Despite having 6% (6.9 million MT) of the world's rare earth reserves, India generates only 1% (2,900 MT) in 2023 of global output and imports most of such materials [1]

In Asia, fourteen countries have rare earth elements deposit. Japanese companies are constructing joint venture with five of them, including Vietnam, India, Mongolia, Kazakhstan and, Kyrgyzstan [2]. Apart from these countries, other Asian countries showed interest in REE exploration in 2017 such as Tajikistan, Uzbekistan and, Turkmenistan have also identified significant REE-bearing mineral occurrences including alkaline igneous rocks and carbonatites. There has been continued interest in exploration for REE worldwide [1]

In India rare earth elements accounts for about 5% of the world's REE reserves, currently exploits its primary resource, monazite. Significant REE minerals found in India include ilmenite, sillimanite, garnet, zircon, monazite, and rutile, collectively called Beach Sand Minerals (BSM) [1]. India has almost 35% of the world's total beach sand mineral deposits.

The Chhotanagpur granite gneiss complex (CGGC), an East-West trending mobile belt, is an important constituent of Precambrian terrain of the east Indian shield. Granite Gneiss Mineralogically a gneiss consists mainly of feldspar and quartz with variable amounts of mica, amphibole, and pyroxene with a banded texture. It spans the states of Jharkhand, Bihar, West Bengal, Uttar Pradesh, Chhattisgarh, and Odisha, covering an area of 100,000 square kilometres. In CGGC, rare earth element (REE) and rare metal (RM) containing minerals are primarily confined to granites which are further classified into two types viz., grey granitoid and pink granitoid and pegmatite phase. CGGC are regarded a potential belt for inland placer deposits of HREE and Y and for associated LREEs. Xenotime represents the HREE and Y phase whereas monazite represent LREE phase [3]

1.1 State of The Art

While named "rare" earth elements, they are in fact not that rare and are relatively abundant in the Earth's crust. What is unusual is to find them in quantities sufficient to support economic mineral development, especially in countries with more stringent mining laws and environmental programs.

The rare earth group contains 17 elements, namely, scandium (Sc), yttrium(Y) and lanthanides (15 elements in the periodic table with atomic numbers from 57 to 71, namely, lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu).

Although, they tend to occur together, the 15 lanthanide elements are divided into three groups – light, medium & heavy elements. The **light rare earth elements** - La, Ce, Pr, Nd, and **middle & heavy rare earth elements** – Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y. Sc is of dispersed

elements, and Pm does not exists in nature. (Chen et al,.2011) Generally, the light rare earth elements are more common and more easily extracted than the heavies. Despite its low atomic weight yttrium has properties more like the heavy lanthanides and is included in this group. Scandium, besides its occurrence with other rare earth elements is also found in several minerals.

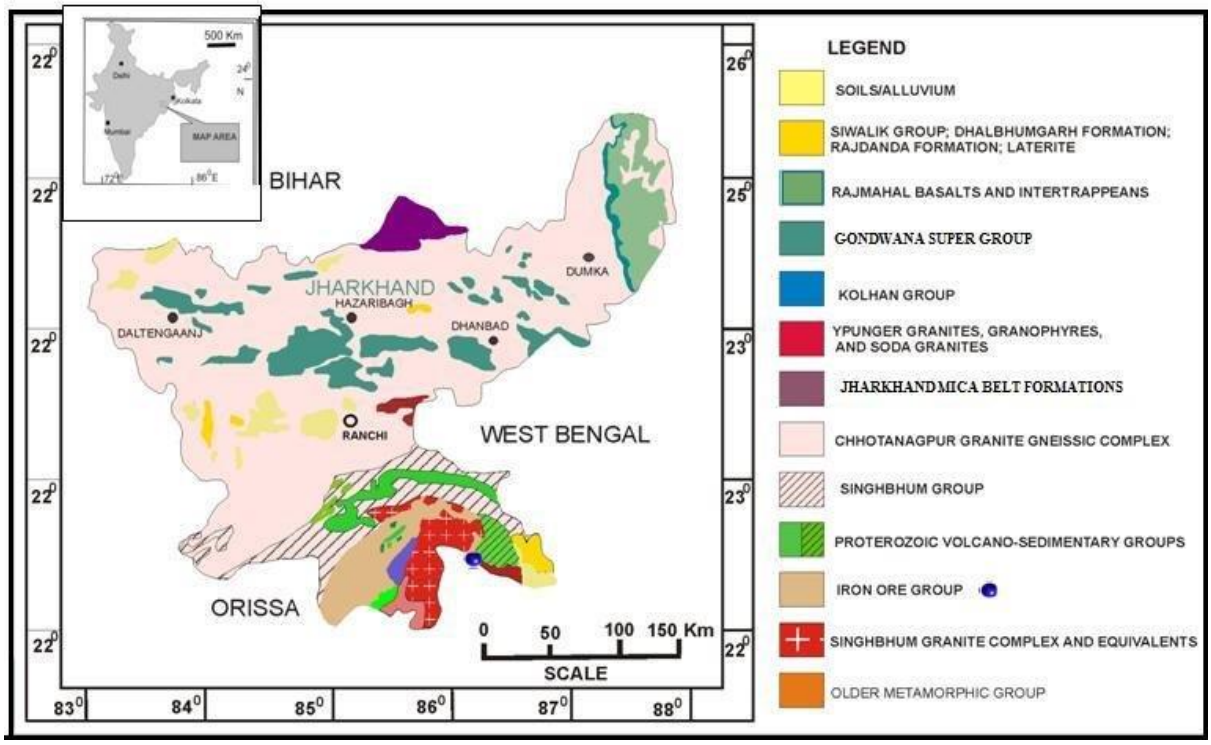
13.07 million tonnes in-situ monazite (containing ~55-60% total Rare Earth Elements oxide) resource occurring in the coastal beach placer sands in parts of Kerala, Tamil Nadu, Odisha, Andhra Pradesh, Maharashtra, and Gujarat and in the inland placers in parts of Jharkhand, West Bengal, and Tamil Nadu. More than 80 % of the usage of rare earths in value terms is in RE permanent magnets which require Magnetic REE i.e. Neodymium, Praseodymium, Dysprosium and Terbium. These are precious REE since they find use in energy transition initiatives. High value REE are Dysprosium and Terbium which are not available in extractable quantities in Indian reserves already under exploitation. In Indian deposits, only Neodymium and Praseodymium are available and are being extracted up to 99.9 % purity level. Neodymium and Praseodymium occur in the BSM ore of Indian deposits to the extent of 0.0011 to 0.012%. (Report from: Department of Atomic Energy, Posted On: 06 APR 2023 4:53PM by PIB Delhi). CII (Confederation of Indian Industry) suggested that an 'India Rare Earths Mission' be set up manned by professionals, similar to the India Semiconductor Mission, as a critical component of the Deep Ocean Mission. The industry group has also proposed including rare earth minerals into the 'Make In India' campaign, which focuses on innovative materials such as permanent magnets derived from rare earth minerals.

1.2 General Geology & Topography:

Physiographycally Jharkhand is largely defined by Chotanagpur plateau region and other distinct geomorphic features. Chotanagpur plateau extended from western part of state to border of West Bengal in east characterized by different steps i.e. level of distinct type of structure and lithological character such state is a *part of Indian peninsular belt.*

The whole of Singhbhum is considered natural *geological museum*. Geologically it consists several rocks ranging from Precambrian to Cenozoic era. The most predominant rock of state comprises of archaean rock associated intrusive and sedimentary belongs to vindhyan and gondwana. The rajmahal traps lying in N-E extremety of chotanagpur plateau consist of Jurassic volcanic lava flow the archaean metamorphic occur in East and West Singhbhum, Ranchi, Gumla, Lohardaga, Hazaribagh, Dumka, etc. they are represented by sediments of quartzite, metabasic (amphibole) and other basic intrusive.

Structurally state can be divided into south Singhbhum province and north Chotanagpur province divided by Tamar katra fault. The southern is known as Singhbhum thrust zone which is known as store house of important minerals.



Geological map of Jharkhand showing the study area location (after Mahadevan, 2002)

1.3 RANCHI (TUPUDANA GRANITE QUARRY)

The study area is Located at about 16 km from Ranchi on Ranchi-Khunti State Highway in Pithiyatil, Tupudana of Ranchi District, southern part of Jharkhand state. The region is underlain by Chhotanagpur gneiss – granulite complex of Precambrian age (Ghose et al. 1973)

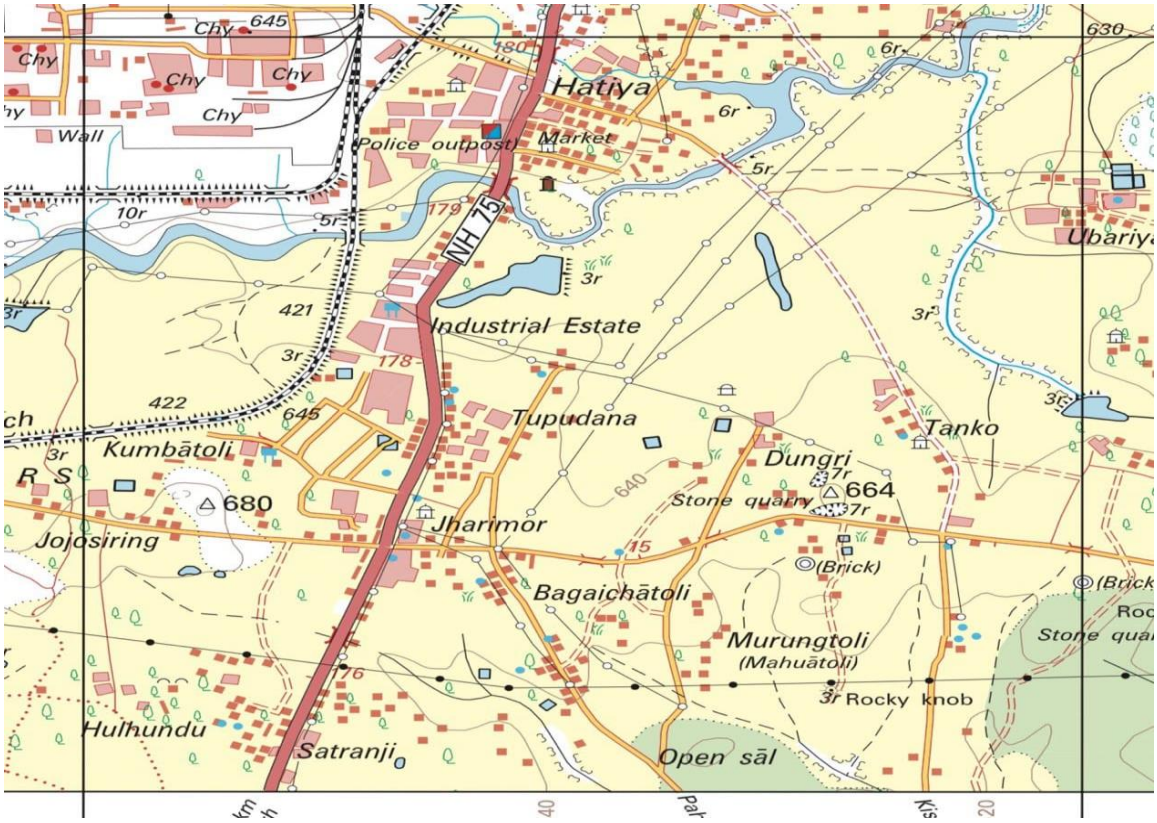
Location

Latitudes of 23˚ 15′58″ N

Longitudes of 85˚ 17′50″E

Elevation 692.53m

Toposheet: Toposheet No. 73E/7 Ranchi



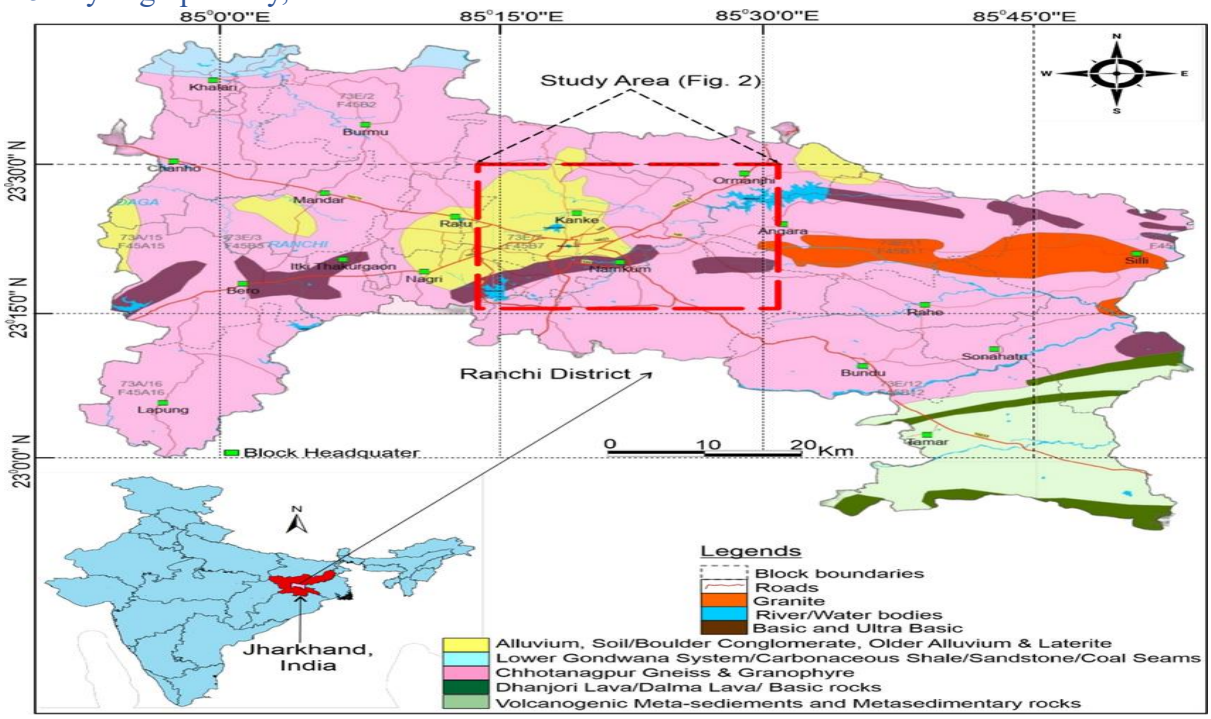
Toposheet: Toposheet No. 73E/7 Ranchi

1.4 Geology

In the past, the area had a basin where sedimentary rocks were deposited, and later these rocks metamorphosed and formed metamorphic rocks. The transformation of granite into granite gneiss results in gneissose structure. The area chiefly composed of granite and granite gneiss. This area has enclaves or relicts of amphibolite and mica schists.

Three generation of pegmatite veins were observed in this area. This area consists of pink granile, grey granite, leucogranite, migmatites, myrmekite, Rapakivi granite. This area has numerous pegmatite or quartz veins occurring in parallel or horizontal banded form and is called en-echelon structure. Due to high tectonic activity, there are folding in pegmatite and quartz veins. This area is of high-grade regional metamorphism. In this area small amounts of pyrite/gold are found in quartz veins and low amount of hexagonal beryl are found.

1.5 Physiographically, the Ranchi area is divided into three areas.



Geological map of Jharkhand (Reference JSAC & DMG, Ranchi, Jharkhand)

• Northern region- Potpotto – jumar Basin

• Central region – Manatu-Booty upland

• Southern region- flat peneplain (elev. Is 2040ft)

These contain rechain of dome shape hills of gneissic rock. The important hills are Misirgonda, Tagore hill, Badamandi Hill, Argora hill and Hehal hill, Rifle Hill which is the highest point at ranchi. The peneplain flat area- Jagannathpur hill upto Tagore hill.

1.6 General geological succession of Ranchi area

Lateritic soil	
Laterite	
Quartz vein	
Aplite	
Pegmatites	Of three generation
Chhotanagpur granite/granite gneiss	
Amphibolites	Basic intrusive rock
Crystalline limestone	Metasedimentary rock
Khondalite	
Quartzite	
Miza Schist	

1.7 Topography of Ranchi:

Ranchi is located between Latitude - 23°20'30" N to 23°25'30" N and Longitude - 85°16'E to 85°22'E. The tropic of CANCER at $23\frac{1}{2}^{\circ}$ North passes through Ranchi District (at Ormanjhi). The average altitude of Ranchi is 600 meters above the sea level with undulating land features. The physiographic characteristics of the district are rich. It has waterfalls, hills, and land with avalanches. Ranchi is surrounded by green forest. Ranchi has a humid subtropical climate. However, due to its position and the forests around the city, it is known for its pleasant climate. Its climate is the primary reason why Ranchi was once the summer capital of the undivided State of Bihar. Ranchi used to be a preferable hill station in the past. Temperature ranges from maximum 42 to 20 °C during summer, and from 25 to 0 °C during winter. December and January are the coolest months with temperature getting to freezing point in some places of the city. The annual rainfall is about 1430 mm (56.34 inches). From June to September the rainfall is about 1,100 mm. The total area covered by the Ranchi municipal area is 175.12 square kilometres.

Ranchi is located on the southern part of the Chota Nagpur plateau which forms the eastern edge of the Deccan plateau. Ranchi is referred to as the "City of Waterfalls", due to the presence of numerous large and small falls of around the close vicinity of the city. The most popular ones are Dassam Falls, Hundru Falls, Jonha Falls, and Panchghagh Falls.

The Subarnarekha River and its tributaries constitute the local river system. Dams in Kanke, Rukka and Hatia have been built over these channels to cater to the water requirements of majority the population.

1.8. KHUNTI (CHELANGI MINE)

The area for Ornamental Granite mining lease over an area is a non-forest Govt. land situated in village- Chalangi, Thana – Khunti, in the district of Khunti of Jharkhand State. The area is in part of survey of India toposheet No. 73 E/8. The granite project has been under the supervision of Jharkhand State Mineral Development Corporation Ltd (JSMDC).

1.9 Accessibility:

The Ranchi – Khunti NH – 75(E) Road is crossing to the west of the lease hold area at approximately 3.00Kms. A cart road connects Ranchi – Khunti NH – 75(E) road at Hutar Chowk. The nearest Railway Station is Hatia which is around approximately 20Kms.

Location:
Latitude: 23008'20" N to 23008'27" N
Longitude: 85017'33" E to 85017'38" E
Altitude: 603m

Geological map of Khunti (District Survey Report Prepared in accordance with Para 7 (iii) of S.O.3611 (A) Dated 25th July,2018 of Ministry of Environment, Forest, and Climate Change Notification)

1.10 General Geology:

The area is basically consisting of granite rock. The grey coloured granite rock which has essential minerals like quartz, feldspar, biotite, and tourmaline as accessory mineral. the whole area is intruded by various veins. Amphibolite and biotite schist occur as enclave/relict. Granite is exposed in the area in the form of sheet rock and occur also in flat land from the surface.

1.11 Topography of Khunti

The northernmost and southernmost parts of the district are covered with hillocks and forests. The district has different relief because of its physiography as it consists of plateaus of having different heights. Altitude of the area varies from 500m to 700 m above mean sea level in general. There are many hillocks through the district having altitude 700 m above mean sea level. The term Pat represents a feature like a table with steep edges around and a flat top. The district is the part of Chhotanagpur plateau. Chhotanagpur Plateau consisting mainly of gneisses and granite and partly of schists and other Dharwar rocks. The other plateaus are the Rajmahal Hills and the Kaimur Plateau. These plateaus are separated by the narrow and steep slopes known as scarps. It is believed that before the Chhotanagpur Peneplain was successfully uplifted thrice by the side effect of the three violent Himalayan movements in Tertiary times continued till Pleistocene times resulting in well-known waterfalls like Hundru, Jonha, etc. on the scarps. The first upliftment took place during the Eocene to Oligocene period creating Pat

region, the second one during Miocene forming the Ranchi and Hazaribagh Plateau and the third one during Pliocene and Pleistocene period uplifting the outer Chhotanagpur Plateau. All plateaus are the parts of the same plain successively uplifted during Tertiary and Pliestocene times. Marvelous eye catching rare geological/geomorphological features like rejuvenated meandering and deep cutting young rivers. It is rare because of combination of senility with the character of young rivers. The district has the luxuriant forests and lush green rolling seasonal meadows. Magnificent undulating hills and valleys are the special attraction. A combination of table-top flat lands and the peneplain with dome shaped exfoliating hillocks resembling like inverted Nagara (drum) are spread over the district. Further, the Tors or the balanced diamond shaped rocks are also present wonderful nature of the state.

1.12 Geological Succession of Khunti area:

Succession of the area: Lateritic soil Laterite Quartz vein Aplite Pigmatite vein	
Chotanagpur granite/ Granite gneiss	
Amphibolite	Basic intrusive rock
Crystalline limestone Khondalite Quartzite Mica schist	Metasdimentary

2. OBJECTIVE OF THE INVESTIGATION AND MOTIVATION:

The goal is to find out the amount of rare earth elements (REE) in granite rock samples, their presence in the Earth's crust, their mineralogy and, different types of deposits particularly in the areas of Ranchi (Tupudana granite quarry) and around Khunti (Chalani mines) of Chhotanagpur plateau, Jharkhand. Rare-earth elements (REE) are essential components of products in a wide range of applications. The role of REE in agriculture and medical, including new emerging ones, is discussed.

3 PROBLEMS TO BE INVESTIGATED:

- To identify the Rock type and its characteristics.
- To determine the concentration of major accessory minerals in a rock, regardless of their state.
- Study of thin section to investigate the optical properties of the minerals in the rock and to identify the origin and evolution of the parent rock.
- To estimate the concentration of rare earth element (REE) in granite rock samples of the study area.
- Its impact on public health, agriculture, environment, and the extent to which REE can be used in various ways based on its quality.

4. RESEARCH DESIGN AND METHODOLOGY:

The proposed approach for the research study is as follows:

1. Detail literature survey.
2. Detailed field work and geological mapping of the lithological units in the study area and the adjoining areas.
3. Systematic sampling of the rocks from the mineralized zone within the study area.
4. Preparing thin section for microscope analysis, mineralogical studies, ore petrographic analysis and mineral paragenesis.
5. To identify and analyses the associated important economic minerals.
6. Interpretation of data by integrated study on structure, geology, petrography, chemistry, and economic potentiality.
7. Study of geologic sample on Scanning Electron Microscopy (SEM).
8. Preparing the rock powder sample for geochemical analysis and fully dissolving it to acquire precise and accurate data for geological materials in most investigations.
9. Acid Digestion of the Powdered Sample to be done for wet-chemical microwave sample preparation technique involve the use of mineral acids such as hydrofluoric acid (HF), perchloric acid ($HCLO_4$), or nitric acid (HNO_3), (Yokoyama, Makishima, and Nakamura 1999; Zawisza et al.
10. Inductively Coupled Plasma Mass Spectrometer (ICP-MS) is an analytical technique used for elemental determination.

5. TOOLS TO BE USED IN THE COLLECTION OF DATA:

1. GPS
2. XRF
3. XRD
4. Field books.
5. Hand lenses
6. Rock hammers
7. Rock Chisels
8. Pencil Magnet
9. Geologist's Tape Measure
10. Topographic maps
11. Geological maps
12. Petrographic microscope
13. Magnetic compasses

(Other tools can also be used during research work depending on the availability).

6. SIGNIFICANCE OF THE WORK, ITS RELEVANCE TO THE PRESENT-DAY PROBLEM AND NEED OF THE SOCIETY:

Rare earth elements are likely to remain an important part of our future—from quantum computing and material sciences, to medical applications and advances in green technology. They are essential in efforts to reduce greenhouse-gas emissions enough to avoid the most devastating consequences of climate collapse. Ongoing moves away from internal combustion cars to electric vehicles will also increase demand for rare earth magnets and batteries.

To meet future demand, mining companies have proposed opening new mines and building new processing plants in many parts of the world. Some plans sound like science fiction, such as deep-sea mining or extracting rare earths from the acidic wastewater draining from abandoned mines.

Another idea is to better design our technologies so we can reduce or more easily reuse the rare earth metals inside of them. In the wake of the 2010 crisis, car makers redesigned vehicles to use smaller amounts of rare earth metals. Consumer electronics could be designed to be more easily repaired and upgraded rather than simply discarded. Research into new methods to recover rare earths from electronic waste, for instance, could reduce the number of metals that need to be produced by mining and refining.

Significance of REE?

- They have distinctive electrical, metallurgical, catalytic, nuclear, magnetic, and luminescent properties.
- They are strategically very important due to their use of emerging and diverse technologies that cater to the needs of current society.
- Its usage ranges from daily use (e.g., lighter flints, glass polishing mediums, car alternators) to high-end technology (lasers, magnets, batteries, fiber-optic telecommunication cables).
- Even futuristic technologies need these REMs (For example high-temperature superconductivity, safe storage, and transport of hydrogen for a post-hydrocarbon economy, environmental global warming, and energy efficiency issues).
- The global demand for REMs has increased significantly in line with their expansion into high-end technology, environment, and economic areas.
- They are extremely important for many modern technologies, including consumer electronics, computers, and networks, communications, clean energy, advanced transportation, health care, environmental mitigation, national defence, etc.
- Due to their unique magnetic, luminescent, and electrochemical properties, they help technologies perform with reduced weight, reduced emissions, and energy consumption; therefore, giving them greater efficiency, performance, miniaturization, speed, durability, and thermal stability.

7. CONTRIBUTION TO THE EXISTING KNOWLEDGE, FUTURE WORK:

7.1 Khunti (Chelangi Mine)

1. *Apophyses (tongue like vein):* Apophyses is the branch of vein which appears as tongue like form.
2. Fine grained and thinner quartz vein and medium to coarse grained and thicker pegmatite vein appears.
3. The granite intrusion in the existing granite rocks is an excellent.
4. A fragment of feldspar trapped between the granite. The possibility is that cooling environment in which the fragment developed or during crystallization the fragment comes from the pegmatite vein.
5. Three generation structure (oldest granite rock, intermediate pegmatite vein and newer Quartz vein) appears in the Chelangi granite project. The age of the vein can be determined by texture and composition.

6. Single pegmatite vein with two types of grain size (finer is below and coarser is above) appears, all happen due to cooling effect of magma or magma composition. Cooling temperature could not be differentiated in short duration of time.
7. Large size of vein of Quartz, Feldspar, Biotite, and Muscovite is present.
8. Presently Chelangi granite project has been stopped due to environmental issue.

7.2 Ranchi (Tupudana Granite Quarry)

1. The pegmatite vein has composition of Quartz, orthoclase feldspar, biotite.
2. There are eye-shaped lenticular veins of mineral grains or mineral aggregate visible in some foliated metamorphic rocks. Feldspar, quartz, and garnet are common minerals which form augen
3. The older pegmatite vein intruded by the newer vein and forming 1st gen and 2nd gen pegmatite vein.
4. Biotite schist and amphibolite is found in enclave.
5. A grain of pyrite is found in a pegmatite vein at Tupudana granite area.

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